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Indicators and Associated Decay of Engelmann Spruce in Colorado

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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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FOREST SERVICE U. S. DEPARTMENT OF AGRICULTURE

(ABOVE)

A sporophore of Fomes pini formed on tree trunk.

(COVER)

Six-log Engelmann spruce exhibiting cull indicators in upper crowns. Trees (left to right) contain:

Dead leader,
Dead top with adjacent dead rust brooms,
Live rust brooms,
Broken top.

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INDICATORS AND ASSOCIATED DECAY OF ENGELMANN SPRUCE IN COLORADO[1]

by

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and

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[1] Acknowledgment and appreciation are expressed to the Division of Timber Management, Denver Regional Office of the U.S. Forest Service, and the staffs and rangers on the National Forests for assistance in this study; and to the personnel of the Forest Disease Laboratory, Laurel, Maryland, for identifying cultures of decay fungi.

[2] Central headquarters maintained in cooperation with Colorado State University at Fort Collins.

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by
Thomas E. Hinds and Frank G. Hawksworth

Engelmann spruce-subalpine fir is one of the important forest types in the Central Rocky Mountains, and is the most extensive type in Colorado. Engelmann spruce is usually the predominant species. Most spruce-fir stands are mature to overmature.[3] Extensive stands are found in western Colorado between 9,000 and 11,000 feet, but the type extends from 8,000 to 11,500 feet.[4]

Mature spruce sawtimber trees vary from two to five logs (log length of 16 feet) in merchantable height throughout most of the range, but often grow to a height of as much as eight logs on the San Juan National Forest in southwestern Colorado.

Cutting was relatively limited prior to about 1950. Since then Engelmann spruce has been the leading species in lumber production, and in 1962 the spruce saw-log cut of 89 million board feet amounted to almost half of the State's output for all species.[5]

This study was undertaken to determine (1) what abnormalities are indicative of decay in Engelmann spruce in Colorado, (2) the amount of cull associated with such indicators,[6] and (3) the identification of the fungi responsible for decay.

Review of Previous Work

In 1950, Hornibrook[7] published the only previous report on the determination of decay in Engelmann spruce in Colorado by external indicators. This study, which also included lodgepole pine and subalpine fir, was based primarily on dissection of trees on the Fraser Experimental Forest, with supplemental work at some other localities on the Arapaho National Forest. Most of the cull in the study was associated with relatively few defect indicators. In order of importance they were: Conks or fruiting bodies, swollen knots, sound produced when a tree was pounded, decay on

[3] *LeBarron, R. D., and Jemison, G. M. Ecology and silviculture of the Engelmann spruce-alpine fir type. J. Forest. 51: 349-355, illus. 1953.*

[4] *Alexander, R. R. Silvical characteristics of Engelmann spruce. U. S. Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Sta. Pap. 31, 20 pp., illus. 1958. Ft. Collins, Colo.*

[5] *Miller, Robert L., and Choate, Grover A. The forest resource of Colorado. U. S. Forest Serv., Res. Bull. INT-3, 54 pp., illus. 1964. Intermountain Forest and Range Exp. Sta., Ogden, Utah.*

[6] *Cull is usually considered to be that portion of a tree or log of merchantable size rendered unmerchantable because of poor form, limbyness, rot, or other defect. That is, cull is the deduction from gross volume made to adjust for defect. Cull, as employed in this paper, is limited to the defect caused by rot and does not include loss of volume due to other defects.*

[7] *Hornibrook, E. M. Estimating defect in mature and overmature stands of three Rocky Mountain conifers. J. Forest. 48: 408-417, illus. 1950.*

an increment core, fire scars, forks, cankers, frayed branch stubs, lightning scars, frost and wind cracks, and top injuries. By use of these indicators, Hornibrook was able to estimate net board-foot volume in a predominantly pine stand 31 percen defective within 2.5 percent. In a predominantly spruce stand, which was 15.4 percent defective, the estimated defect was within 2.2 percent. Accuracy of the defect estimates by tree species, however, was not given. The relative importance of a given indicator in each of the three species was not listed except in a few instances.

Hornibrook listed decay as responsible for 87 percent of the defect in the three tree species as a whole. Nearly three-fourths of the decay was caused by Fomes pini, and three fungi (F. pini, Polyporus circinatus, and Coniophora cerebella) accounted for about 90 percent of the decay volume. In all, 11 species of decay fungi were listed; none was listed as unknown.

Methods

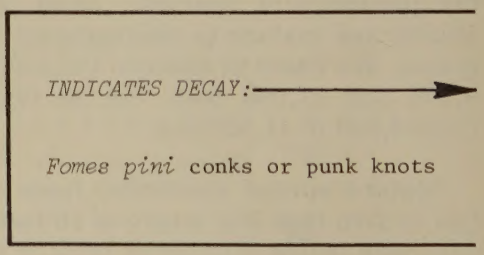
The present study was conducted in two general parts. The first part, the intensive study, involved dissection of trees with only one abnormality in a certain portion of the bole. In the second part, the extensive study, the reliability of the indicators found to be important in the intensive study were tested in commercial logging operations.

Intensive Study

Study areas usually under 20 acres in size were located throughout the spruce-fir type so that stands of different age classes and sites could be compared. The areas, usually located within a commercial sale, were selected so that the site was as uniform as possible.

From 15 to 65 trees with various abnormalities and 1 to 6 trees with no abnormalities were selected in each study area. Possible indicators of decay were recorded before and after each tree was felled. Total height, diameter at breast height, age at stump height (1 foot), and crown class were recorded for each tree. We tried to leave the sound portions of the trees in 16-foot logs, but additional cuts were made to determine the extent of any rot column. Cuts were made at all external abnormalities which were believed to be possible indicators of decay. If rot was present, we determined whether or not it was associated with the indicator. The extent of rot was delineated by cuts above and below the indicator. Complex decay columns associated with more than one indicator were discarded in calculating indicator defect Isolations were attempted whenever the causal fungus was questionable.

Inside bark and rot diameters were measured so that tree and decay volumes could be calculated on a cubic-foot and board-foot basis.



Extensive Study

In the extensive study, plots of approximately 1 acre were set up in spruce-fir sale areas just before they were cut. All trees larger than 9.6 inches in diameter were tagged. The d.b.h., crown class, and abnormalities that might indicate decay were recorded for each tree. The trees were then felled by loggers and bucked into 16-foot or smaller logs, the usual local practice. The total height was then measured to the closest foot. Inside-bark and rot diameters were measured at various points up the tree. The trees were then reconstructed on cards, and the cubic-foot gross and decay volumes calculated as in the intensive study. Board-foot gross and cull volumes were measured directly from the logs according to the regional scaling practice.

Computation Procedures

Cubic-foot volumes for each 16-foot log were determined by use of Smalian's formula:

$$\frac{A + a}{2} \times L$$

where

A = area of top cross section in square feet,
a = area of bottom cross section in square feet,
L = length in feet.

A minimum top diameter of 5.6 inches was used. This same formula was used to calculate cubic-foot decay volume if the rot extended through the log. If decay was present on only one end of the log, the rot volume was calculated as a cone.

Board-foot volumes were determined by plotting the trees on cards and marking off 16-foot logs. A 3-inch trimming allowance was made, and a top diameter of 7.6 inches was used. The top log was the largest even-foot length possible between 8 and 16 feet. Board-foot decay was calculated by using the standard squared-defect method:

$$\frac{W \times H \times L}{15} = \text{decay volume in board feet}$$

where

W and H = cross-section dimensions, in inches of the decay column (1 inch added to each dimension for waste),
L = length of decay column, in feet.

Results

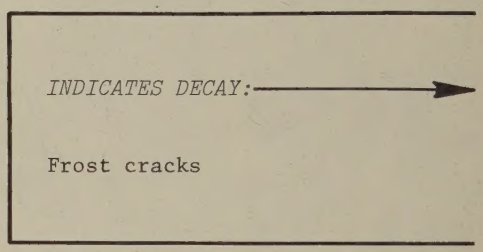
Cull Indicators

Sample plots were established in nine National Forests in Colorado. A total of 21 plots, 13 intensive and 8 extensive, with 1,027 merchantable Engelmann spruce was examined, and plot data summarized (table 1).

Over 1,300 abnormalities of 24 types were examined in the intensive study, but only 11 were found to be consistent indicators of decay. Trees in the intensive study with no abnormalities averaged 4 percent board-foot cull, so only abnormalities associated with more than 4 percent cull were considered to be decay indicators.

For the following analyses, data from the intensive and extensive studies were combined. Decay associated with indicators accounted for 86 percent of the board-foot cull and 89 percent of all cubic-foot decay. The volume of non-indicated decay was about the same in trees with and without indicators.

Eleven indicators were found to be consistently associated with decay, and the related average cull (table 2). Cull was separated on an indicator basis where the same tree was used in two or more categories. Other abnormalities that were not consistent indicators of decay in Engelmann spruce were: Butt swell, burls, crooks, dead branches, hollow buttress,[8] leaning trees, lightning scars, live rust brooms, recent dead tops, root wounds, and spruce cankers. Board-foot and cubic-foot cull associated with these indicators was less than 4 percent and 1 percent, respectively.



Trees frequently had more than one cull indicator. The proportion of trees with the various indicators in the extensive-study plots is given in table 2. As seen in the table, 43 percent of the trees on the eight study areas (total of 10.2 acres) were free of cull indicators.

[8] *Spruce at high elevations and along stream beds frequently have large lateral roots extending above the ground line near the root collar. Hollow buttress refers to the buttress-like effect characterized by the open air spaces extending beneath these roots and often a foot or more beneath the tree butt.*

Table 1.--Summary of Engelmann spruce cull indicator study plot data

Plot number	Location		Trees	Average age	Site index[1]	Abnormalities	Cull[2]
	National Forest	Ranger District	Number	Years		Number	Percent
INTENSIVE STUDY (1957-58):							
1	Roosevelt	Redfeather	59	443	65	144	--
2	Pike	Bailey	57	294	65	102	--
3	White River	Minturn	41	447	70	141	--
4	Grand Mesa - Uncompahgre	Mesa	45	139	90	89	--
5	San Juan	Mancos	57	309	70	147	--
6	San Juan	Animas	19	210	115	47	--
7	San Juan	Animas	15	213	105	48	--
8	Routt	Hahns Peak	20	223	85	44	--
9	Routt	Hahns Peak	50	243	85	104	--
10	San Isabel	San Carlos	63	312	70	144	--
11	Arapaho	Sulphur	65	253	90	185	--
12	Rio Grande	Del Norte	33	170	80	73	--
13	Rio Grande	Del Norte	24	218	95	80	--
	All intensive plots		548	--	--	1,348	--
EXTENSIVE STUDY (1959):							
14	Pike	Bailey	89	270	55	121	26
15	Pike	Bailey	19	380	55	41	10
16	Roosevelt	Laramie River	52	350	60	85	9
17	Grand Mesa - Uncompahgre	Ouray	54	165	100	108	17
18	Grand Mesa - Uncompahgre	Ouray	81	240	90	108	19
19	Roosevelt	Laramie River	58	419	75	124	15
20	Routt	Bears Ears	67	209	90	80	11
21	Routt	Bears Ears	59	172	85	89	7
	All extensive plots		479	--	--	756	15
	Total, all plots		1,027	--	--	2,104	--

[1] Based on total height and age 100 years at d.b.h. (Hornibrook, E.M. Yield of cutover stands of Engelmann spruce. J. Forest. 40: 778-781, illus. 1942.

[2] In plots 1 through 13, mostly trees with indicators were felled, so no information on average cull was obtained.

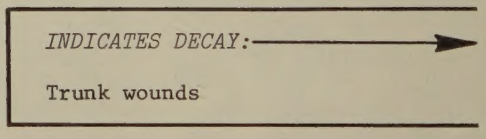


Table 2.--Indicators of decay in Engelmann spruce, and associated cull

Indicator	Extensive plots only	All plots					
	Trees with indicator	Trees	Frequency of decay	Average cull			
	Percent	Number	Percent	Board feet	Percent	Cubic feet	Percent
Fomes pini punk knots or sporophores	2	54	100	260	81	32.7	51
Dead top with adjacent dead rust brooms	1	21	67	180	21	16.0	11
Broken top	2	32	75	90	25	8.0	12
Dead rust brooms	1	44	32	50	11	5.0	6
Frost cracks	9	181	32	50	9	4.2	3
Dead leader	7	86	34	30	11	2.6	4
Basal wounds	33	400	37	30	10	2.1	3
Spike top	5	53	30	30	8	2.9	4
Trunk wounds	23	346	23	30	5	2.2	3
All forks	11	191	23	20	8	2.1	3
Joined at base to another tree	6	77	47	20	11	1.5	4
Trees with none of above indicators	[1] 43	582	12	10	2	.4	1

[1] Includes 11 abnormalities not associated with decay (frequency of 15 percent), and trees with no indicators (frequency of 28 percent).

Cull deductions are customarily based on diameter rather than age, but this could not be done for Engelmann spruce. For this species in Colorado, diameter growth is so slow after about 150 years that there was no well-defined relationship between diameter and age.

The 11 cull indicators consistently associated with decay were divided into 3 classes, based on the average amount of cull (table 3). Cull deductions for these indicators by two age classes are also shown in the table. For all other abnormalities which were not consistent indicators of decay, and for trees with no indicators, average board-foot cull amounted to 2 percent; cubic-foot decay, 1 percent.

The sound emitted by a tree when struck at the base often indicates whether the butt log contains decay. All trees in the study were sounded as high as could be reached with a 4-pound sledge or a double-bitted axe. Hollow trees and trees with large amounts of decay in the base emitted a deep, drumlike note when struck. Trees with no basal decay gave out a sharp, ringing sound when struck, whereas trees with incipient or small amounts of decay did not clearly indicate either. The results of sounding 1,027 trees were as follows:

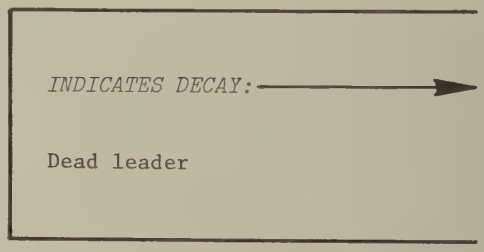
Sounding	Number of trees	Percent of trees with decay	Cull percent of butt log
Hollow	112	96	68
Suspect	383	66	36
Sound	532	30	13

Thus, while this method gives fairly reliable estimates of decay in "hollow" or "sound" trees, the high proportion of trees in the "suspect" class makes sounding of little practical use, except for indicating extensive decay in the butt log.

Fungi Associated with Cull Indicators

Decay fungi were identified for 76 percent of the infections associated with cull indicators, and 88 percent of all infections in the intensive study. The important decay fungi of Engelmann spruce, and average cull associated with them, are shown in table 4.

Cull indicators and associated decays are given in table 5. The frequency of decay fungi does not necessarily indicate their normal frequency in a stand, but rather their association with specific indicators of decay. Generally, there was little relationship between certain indicators and occurrence of specific fungi.



While butt rots accounted for only 12 percent of the decay in the intensive study, it should be noted that only trees with abnormalities were sampled. In these trees, two-thirds

Table 3.--Average board-foot cull deductions by indicator classes for merchantable Engelmann spruce

Indicator			Decay as proportion of gross volume		
			Average age of stand		All stands
Class	Type	Basis	Under 250 years	Over 250 years	
		Number	Percent	Percent	Percent
1	*Fomes pini* punk knots or sporophores	54	68	86	81
2	Broken top or dead top with adjacent dead rust brooms	53	21	25	24
3	Basal wounds, dead rust brooms, dead leader, frost cracks, forks (all types), joined at base to another tree, spike top, and trunk wounds	1,378	8	11	10

of the butt rot was associated with specific external indicators. The proportion of decays not associated with specific cull indicators implies that some of the trees contained decay which entered through roots or by other means that were not noticed during the study. For instance, Pholiota alnicola, Polyporus tomentosus, and Armillaria mellea are known to gain entrance to a tree through its roots, but usually the decay columns do not extend upward to any great extent. The association of P. tomentosus with trunk wounds, forks, and a broken top is unusual, as are the associations of other butt-rot fungi with trunk wounds and forks.

Fomes nigrolimitatus is usually considered to be a basal decay fungus, but it was also associated with trunk wounds and caused considerable cull throughout the tree.

With the exception of Coniophora puteana and Fomes pinicola, the brown rots seldom cause extensive basal decay. C. puteana was the most frequently encountered brown rot, but F. pinicola was equally important in amount of cull. However, F. pinicola usually attacks only dead sapwood and is often associated with old, extensive basal wounds.

Trunk rots associated with cull indicators amounted to 88 percent of the decay in the intensive study. Over 90 percent of the infections were directly attributed to specific indicators. Fomes pini was the most important decay fungus associated with cull indicators. It was the only decay associated with all indicators in table 5, and because the decay was usually more extensive in the tree, it caused the greatest amount of cull. Length of decay columns and average cull of Fomes nigrolimitatus and Stereum sulcatum surpass those of S. sanguinolentum, although the latter was more frequently associated with cull indicators.

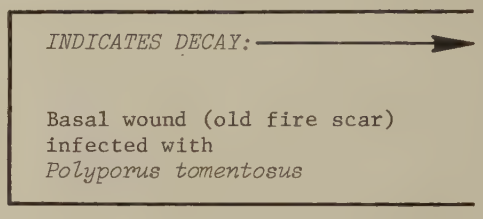


Table 4.--Important decay fungi of Engelmann spruce

Fungus	Infections		Average cull		Average decay column
	No.	Pct.	Bd.ft.	Cu.ft.	Ft.
WHITE BUTT ROTS:					
Fomes nigrolimitatus (Rom.) Egel.	13	3	150	14.7	25
Pholiota alnicola (Fr.) Singer	18	4	90	3.7	8
Polyporus tomentosus Fr. var. *circinatus* (Fr.) Satory & Maire	17	4	60	3.5	10
Corticium radiosum (Fr.) Fr.	11	3	50	3.3	8
Armillaria mellea (Fr.) Quel.	4	1	20	.3	3
Pholiota sp.	3	1	20	4.7	5
BROWN BUTT ROTS:					
Coniophora puteana (Schum. ex Fr.) Karst	19	4	70	3.3	9
C. olivacea (Fr.) Karst	6	1	10	.2	3
Fomes pinicola (Swartz) Cke.	3	1	70	3.5	15
WHITE TRUNK ROTS:					
Fomes pini (Fr.) Karst	143	34	190	21.2	35
Stereum sanguinolentum (Alb. & Schw. ex Fr.) Fr.	122	29	80	5.9	21
S. sulcatum Burt.	28	7	150	15.8	24
S. chailletii (Pers. ex Fr.) Fr.	7	2	50	4.3	19
BROWN TRUNK ROTS:					
Trametes serialis Fr.	6	1	50	4.0	16
Peniophora septentrionalis Laurila	6	1	30	2.1	13
Stereum abietinum Pers.	3	1	100	13.9	30
Lenzites saepiaria (Wulf.) Fr.	3	1	90	7.1	21
OTHER DECAY FUNGI[1]	8	2			
TOTAL ROTS	420	100			

[1] Fungi that constituted less than 1 percent each of the total identified infections were:
Butt rots -- *Pholiota squarrosa* (Fr.) Kummer; *Collybia velutipes* Curt. ex. Fr.; *Coniophora arida* (Fr.) Karst.; *Polyporus balsamens* Pk.
Trunk rots -- *Trechispora raduloides* (Karst.); *Poria ferrugineo-fusea* Karst.; *Fomes roseus* Alb. & Schw. ex Fr.

Field Application of Cull Indicators

The cull percentages in table 3 are averages, so they cannot be expected to give decay estimates for individual trees or small numbers of trees. We suggest that averages based on stand age be used when possible on small areas. On larger areas where stands differ or contain mixed age classes, then the average for all stands should be used.

All indicators apply to the merchantable parts of the bole only--that is, below a 6-inch top diameter. The cull deductions for each indicator should be added for the merchantable tree, unless two or more indicators occur in the same part of the bole. In this case, use the highest deduction. For example, if a broken top and fork occur on the same part of the bole, deduct only for the broken top.

The cruiser should record the gross volume of each tree, and note the number of indicators in the three classes for all trees tallied. Multiply the number of indicators in each class by the appropriate cull percent. Then divide the total of all three classes by the number of trees in the sample. To obtain the total cull deduction, add a flat cull factor of 2 percent (for other non-indicated decay).

As an example of the application of these cull data, the results for the four plots over 250 years old (table 1--plots 14, 15, 16, and 19) will be given. There were a total of 218 trees on these plots, with 266 indicators in the 3 indicator classes as follows:

Indicator class	Percentage deduction (table 3)	Number of indicators	Total deduction
1	86	7	602
2	25	8	200
3	11	251	2,761
Totals	--	266	3,563

This total of 3,563 is divided by the number of trees in the sample (218) to give a deduction of 16 percent. To this is added the flat cull factor of 2 percent, to give an estimated total cull of 18 percent. Cull based on actual measurement of decay in these plots was 18.1

Table 5.--Fungi associated with cull indicators of Engelmann spruce

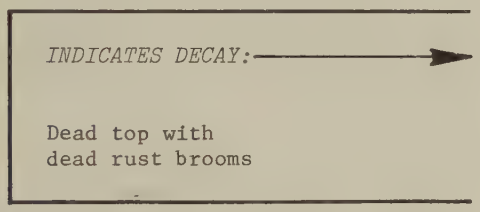
Fungus	Infections	Cull indicator										
		Dead top with dead rust brooms	Broken top	Dead rust brooms	Frost cracks	Dead leader	Basal wound	Spike top	Trunk wound	Forks	Joined base	Other[1]
		Number										
Fomes nigrolimitatus	11		1		1			1	5		2	1
Pholiota alnicola	7				1		4		1			1
Polyporus tomentosus var. *circinatus*	13		1		1		4		1	1	2	3
Corticium radiosum	4				1		3					
Pholiota sp.	2						1		1			
P. squarrosa	2				1				1			
Collybia velutipes	1						1					
Coniophora puteana	16						6		6		1	3
C. olivacea	3						1					2
Fomes pinicola	3						1		2			
Coniophora arida	1						1					
Polyporus balsameus	1									1		
Fomes pini	[2] 137	6	7	20	2	5	5	4	8	21	8	8
Stereum sanguinolentum	107	3	9	4	6	5	24	5	28	8		15
S. sulcatum	28	2	1	3	5		1		3	4	4	5
S. chailletii	7						3		2	1	1	
Trechispora raduloides	1									1		
Poria ferrugineo-fusca	1									1		
Trametes serialis	6	1	3						2			
Peniophora septentrionalis	3								3			
Stereum abietinum	3							1	1	1		
Lenzites saepiaria	3		1				2					
Fomes roseus	1		1									
TOTAL	361	12	24	27	18	10	57	11	64	39	18	38

[1] Decay fungi associated with other abnormalities not listed.
[2] Includes 43 infections associated with punk knots and sporophores.

percent. Estimated and actual cull percentages for the 4 plots under 250 years old were also within 1 percent.

Board-foot cull can be obtained by the percent deductions in table 3, or by using the average board-foot cull from table 2. Cull estimates from tables 2 and 3 will give similar results, but table 3 will be easier to use in the field because it has only three indicator classes.

The number of trees to be tallied for reliable cull estimates has not been determined. The number will vary from area to area, because certain indicators are more prevalent in some stands than others. Also, some abnormalities are more reliable indicators of decay than others. For example, all trees with Fomes pini sporophores or punk knots were decayed, as were 75 percent of the trees with broken tops, but decay was associated with only 30 percent of the old, dead spike tops and 23 percent of the forked tops. Since the number of trees that need to be sampled to obtain various degrees of accuracy is not known, it is suggested that all trees on sample plots be tallied.

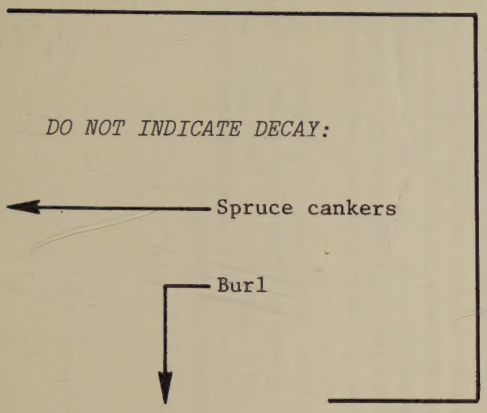


Summary

Information on decay and average amount of cull associated with cull indicators was obtained from over 2,000 abnormalities on 1,027 merchantable Engelmann spruce trees from 21 plots throughout spruce stands in Colorado.

Board-foot percent cull deductions for all stands by three indicator classes was found to be as follows:

Class 1--Fomes pini punk knots or sporophores (81 percent):
Class 2--broken tops or dead tops with adjacent dead rust brooms (24 percent);



Class 3--basal wounds, dead rust brooms, dead leader, frost cracks, all forks, joined at base to another tree, spike top, and trunk wounds (10 percent). A flat cull factor of 2 percent is then added to obtain the total average cull deduction.

The fungi associated with 88 percent of the infections in the intensive study were identified. Butt rots, with the exception of Fomes nigrolimitatus, were not usually extensive or associated with much cull. Fomes pini was the most important decay fungus.

Hinds, Thomas E., and Hawksworth, Frank G.
1966. Indicators and associated decay of Engelmann spruce in Colorado. U. S. Forest Serv. Res. Paper RM-25, 15 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 80521.

Average cull deductions for 11 cull indicators were determined from over 2,000 abnormalities on 1,027 merchantable Engelmann spruce in 21 stands throughout Colorado. On a board-foot basis, Fomes pini punk knots or sporophores caused an 81 percent deduction. Deduction for broken tops or dead tops with adjacent dead rust brooms amounted to 24 percent. Basal wounds, dead rust brooms, a dead leader, frost cracks, all forks, joined at the base to another tree, spike top, and trunk wounds were each responsible for a 10 percent deduction. Fomes pini was the most important decay fungus.

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